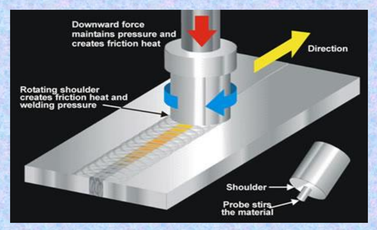
3D Deformation and Strain Analysis in Friction Stir Welded Aluminum using Image Correlation

Author: K. Renee Horton NASA Mentor: Tina W. Malone MSFC EM10 University of Alabama

Friction Stir Welding

• Friction stir welding (FSW) is a solid state joining process invented at The Welding Institute (TWI) in 1991.
•The temperatures experienced near the weld are lower than those experienced during fusion welding
•There are no large density changes due to a solid-liquid transformation.
•The material is joined by locally introducing frictional heat and plastic deformation.
•Certain stresses are associated with the FSW process and the strength of the material must be determined by various test methods.



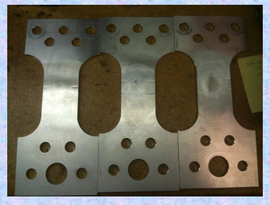
Tensile Test

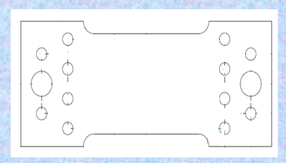
•Most fundamental type of mechanical test you can perform on material .
•The mechanical behavior of materials is described by their deformation and fracture characteristics under applied stresses.
•Specimen is subjected to a continually increasing uniaxial load (force).
•Determination of this mechanical behavior is influenced by several factors that include metallurgical/material variables, test methods, and the nature of the applied stresses.

3D Image Correlation System

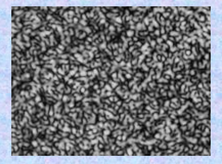
•Is a combination of two-camera image correlation and photogrammetry.
•The process involves applying a random or regular pattern with good contrast to the surface of the test object.
•The pattern deforms along with the object's deformation under different load conditions and is recorded by the cameras.
•Initial image processing defines unique correlation areas known as macroimage facets that are tracked in each successive image with micro-pixel accuracy.
•The center of each facet is a measurement point that can be thought of as an extensometer or strain gauge.

Sample Prep





Tensile Specimens referred to as dog bones are prepared from a schematic drawing.

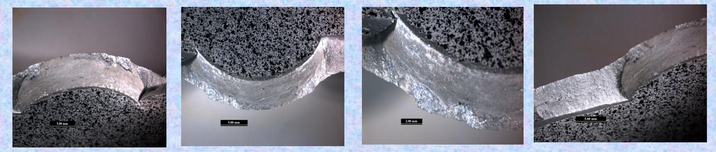


A speckle pattern is then applied to the pattern using a white base with a black speckled pattern applied

Micrographs of fracture surface

(a) (b) (c) (d)

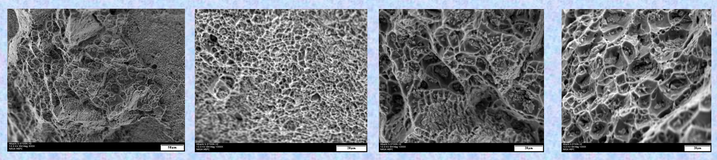
(a) Top right side back view of plug weld (b) Top right side back view of plug weld (c) full view of plug weld top (d) apex of plug weld



(e) (f) (g) (h)

(e) –(h) Front view of plug

Images (a)-(h) taken with a Leica MZ 16A optical light microscopy with 4.5 magnification



(i) (j) (k) (l)

Fracture surface resultant from tensile test showing a cup cone surface. (i)300x (j)-(l) 1000x, surface located right side well of plug weld. Images taken with a Hitachi S-3700N Scanning Electron Microscope. (SEM) Images taken by Dion D. Jones EM31.

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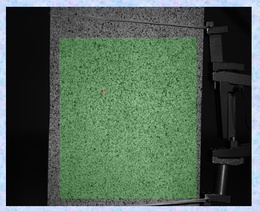
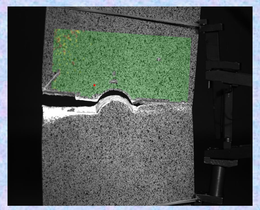
Results and Conclusions

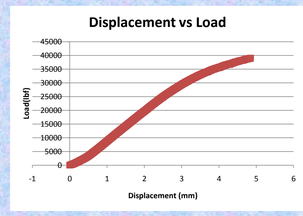


(m)

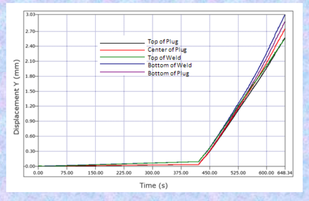


(n)

Above are photo images collected from Aramis data of the specimen as seen by the cameras with an facet field overlay in green. (m) Specimen right before the point of fracture and (n) specimen right after fracture. Based on images and data collected from system failure was contributed to initial weld unzipping from the left of specimen.

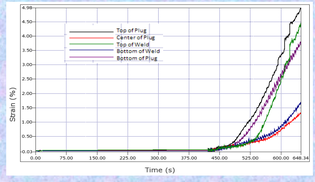


(a)

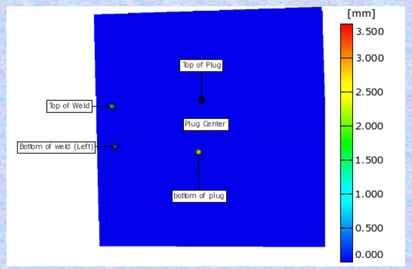


(b)

Graph (a) shows displacement vs. load of the specimen. (b) shows displacement vs. time and (c) shows strain vs. time



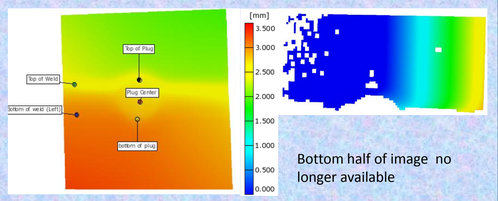
(c)



(o)

Fig. (o) is a 3d representation that shows the specimen under zero displacement and the same would be the same for strain.

Fig. (p) shows displacement of the specimen at the instant before failure on the left and immediately after failure on the right.



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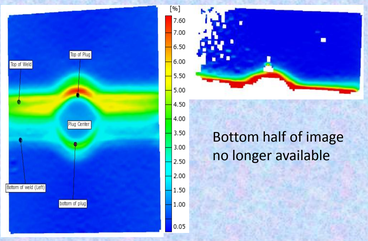
(p)



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(q)

Fig. (q) shows strain of the specimen at the instant before failure on the left and immediately after failure on the right.